Optimal Deployment of Drifting Acoustic Sensors

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LONG TERM GOALS

This is collaborative program comprised of academic, private sector and Navy researchers. The Optimal Deployment of Drifting Acoustic Sensors (ODDAS) program seeks to develop the capability to predict the trajectory of drifting sensors, such as sonobuoys. Emerging antisubmarine warfare programs seek to develop technologies facilitating the deployment of large distributed fields of off-board sensors/sonobuoys with operating lives approaching several days. The acoustic coverage of these systems over multiple day periods is highly dependent on the drift of the individual sensors. Field integrity is often compromised due to local spatial and temporal current variations within the field. The ability to forecast (and hind cast) sensor trajectories, in conjunction with acoustic performance prediction models, will enable operators to select initial deployments such that acoustic coverage will be optimized for the particular mission.

OBJECTIVES

During FY-07 four objectives were pursued:

1. evaluate Sonobuoy Field Drift Model (SFDM) performance against ground truth data from previous sonobuoy field deployments;

2. develop over-the-horizon position tracking sonobuoys and deploy at sea to evaluate the model performance;

3. explore sonobuoy field drift metrics for potential use with future Navy systems;

4. develop sensors capable of collecting and transmitting data for evaluation of Navy standard ocean models and validation of the Sonobuoy Field Drift Model.

APPROACH

During the first three years of this effort the Sonobuoy Field Drift Model (SFDM) was developed. SFDM uses three-dimensional current velocities from any source to develop vertical velocity profiles used to predict a sonobuoy specific drift trajectory of a specific sonobuoy type. A unique sonobuoy model is used for each sonobuoy type, since it accounts for the sonobuoy mass and drag distribution along the sensor chain. Sonobuoy response is predicted using a Navy-standard hydrodynamic cable

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model and, typically, three-dimensional current velocities are provided by existing ocean circulation models such as NCOM.

Our approach is to build on the progress made with the SFDM by assessing the model performance against experimental data, improving the model performance, and developing techniques to use SFDM for drifting sonobuoy field evaluation in a tactical environment.

Assessments of the performance of SFDM can be made by comparing model results to experimental data. Working with the US Navy we have been and will continue to exercise SFDM against available ground truth data from GPS equipped sonobuoys using Naval Oceanographic ocean model current field data. Although this type of analysis is a valuable metric, true validation of SFDM requires the in situ knowledge of both sonobuoy drift and the environment affecting that drift. Therefore, instrumented sonobuoys will be developed that report position and relative flow along the length of the subsurface cable such that the driving vertical current profile is known.

SFDM is being developed in stages. The current version of SFDM does not take into account the effects of winds or waves or the dynamic three-dimensional cable motions. These effects were considered secondary and will be incorporated as indicated by the model validation effort.

An important consideration in the ODDAS program is to integrate the SFDM prediction capability into a system that will benefit US Navy planners. Using SFDM we will explore various metrics to assess sonobuoy field operational performance. We will also work closely with other US Navy existing and emerging programs to find the best way to use SFDM.

This research is the result of collaboration with A.D. Kirwan and Bruce Lipphardt at University of Delaware who supply the current field data and invaluable guidance; Dave Fenton at NAVAIR and Bob Heitsenrether at JHU/APL who have supplied data collected by GPS equipped sonobuoys and Lagrangian drifters during fleet exercises.

WORK COMPLETED

During the current fiscal year significant progress was made in the following areas:

- Raw GPS sonobuoy data from LWAD 06-1 conducted in the East China Sea was obtained from the LAMP program and reconstructed. Comparative SFDM simulations were conducted at all four GPS sonobuoy deployment sites and the results analyzed against the GPS data.

- A low cost, miniature relative flow sensor that could be mounted and deployed on a sonobuoy cable was designed. A prototype was developed and tested in controlled tow experiments. The sensor measures relative flow speed and direction as well as depth. An array of these sensors mounted along the sonobuoy cable combined with sonobuoy drift velocity data would enable the reconstruction of an in situ current profile for validation purposes.

- During this period the SFDM program underwent a major revision to version 3.0. The capability to accept gridded wind data from the Naval Operational Global Atmospheric Prediction System (NOGAPS) and the Coupled Ocean / Atmosphere Mesoscale Prediction System (COAMPS) was implemented. The routine to process the wind data is based on that used to extract current profiles from the current field data – the velocity at the sonobuoy is interpolated in space and time and input into the sonobuoys response model.

- The ODDAS program received endorsement from the LAMP program to participate in the LWAD 07-2 exercise to be conducted in October of 2007 in the East China Sea. To support this exercise four sonobuoys were modified to report in water GPS position using an Inmarsat link over several days. These buoys will be deployed during the first day of LWAD 07-2 and the data will be used for further model performance evaluations.

- Various sonobuoy field quality metrics were evaluated using SFDM. Simulations were conducted using large numbers of closely spaced sonobuoys and metrics such as relative spacing and residence time were mapped as the field evolved.

RESULTS

SFDM simulations were conducted at Sites A, B, C and D from the LWAD 06-1 exercise and the results were compared to the GPS received at the sonobuoys. All of the sonobuoys were type SSQ-53F set to shallow (90 feet) depth and 8 hour life. Average speeds ranged from 0.05 m/s to 0.72 m/s – an indication of the variability of the current fields during this experiment. Figure 1 plots the simulated trajectories (red) with the GPS data (blue) for all of the sites. It is clear that the simulation results from Sites B and C have much better correlation with the measured GPS locations than Sites A and D. This is illustrated further in figures 2 to 5 where selected buoys from each site are examined in more detail.

No conclusions could be immediately drawn to account for the poor performance of the model at sites A and D or the good performance of the model at sites B and C. The error could lie with the sonobuoy response model or with the current field predictions. After meeting with personnel from NRL Stennis Space Center, we concluded that the likely source of error was the current field predictions, but without knowing the actual in situ currents the definitive source of error could not be determined.

Three prototype relative flow sensors were built and tow tested at University of Michigan Marine Hydrodynamics Laboratory Physical Model Basin: an impeller design, a pendulum design and a vortex induced vibration design. The impeller prototype, figure 6, proved to have the most reliable performance although the low velocity performance is less than desired. Figure 7 plots the number of pulses from the sensor (which can be converted to speed) vs. tow speed. The data are consistent and linear throughout the speed range. This low cost design incorporates all off the shelf components and logs one minute averages of current speed, direction and depth every fifteen minutes.

To help evaluate the SFDM version 3 upgrade, NOGAPS and COAMPS data were requested from the Naval Research Lab for the time period and location of the LWAD 06-1 site A deployments. The NOGAPS spatial grid was ½ degree and temporal resolution was 12 hours, while the COMAMPS data was gridded at 12 minute intervals with 12 hour periods. This data was applied to the site A simulation without a logarithmic decrease in wind velocity to the height of the sonobuoy float (a conservative approach). The results of the Site A simulation with and without winds are plotted against the actual GPS data in figure 8. The simulation results do show a change in sonobuoy path in the general direction of the prevailing wind and a drift speed difference with the application of the wind data – an indication that the wind routine is functioning correctly; however, the effect is minor even for this conservative case, and it does not correct the difference from the GPS data.

Work continued in the effort to devise ways to present the results of SFDM simulations to Navy planners in meaningful ways. During this period large simulations were run using the LWAD 06-1 site A and site B EAS-16 current data. Fields of 442 sonobuoys in a 21 by 21 array were modeled over a period of 48 hours (site A) and 72 hours (site B). Buoy trajectories were mapped and made into animations to provide an overview of buoy field dynamics over time. Two metrics were mapped: normalized buoy spacing (example in figure 9) over time and residence time (example figure 10). The utility of these types of plots need to be evaluated.

IMPACT/APPLICATIONS

The ability to accurately predict the path of a drifting acoustic sensor will enable the US Navy mission planner to more effectively utilize available acoustic sensors. By coupling the drift prediction with acoustic modeling into a tactical decision aide, planners can optimize the deployment locations of the buoys to maximize performance according to the mission at hand.

RELATED PROJECTS

This program is closely related to ONR grants N00014-00-1-0019 and N0014-05-0092 as well as the Littoral ASW Multistatics Program (LAMP) and Placement of Active ASW Distributed Systems (PAADS) ONR FNC programs.

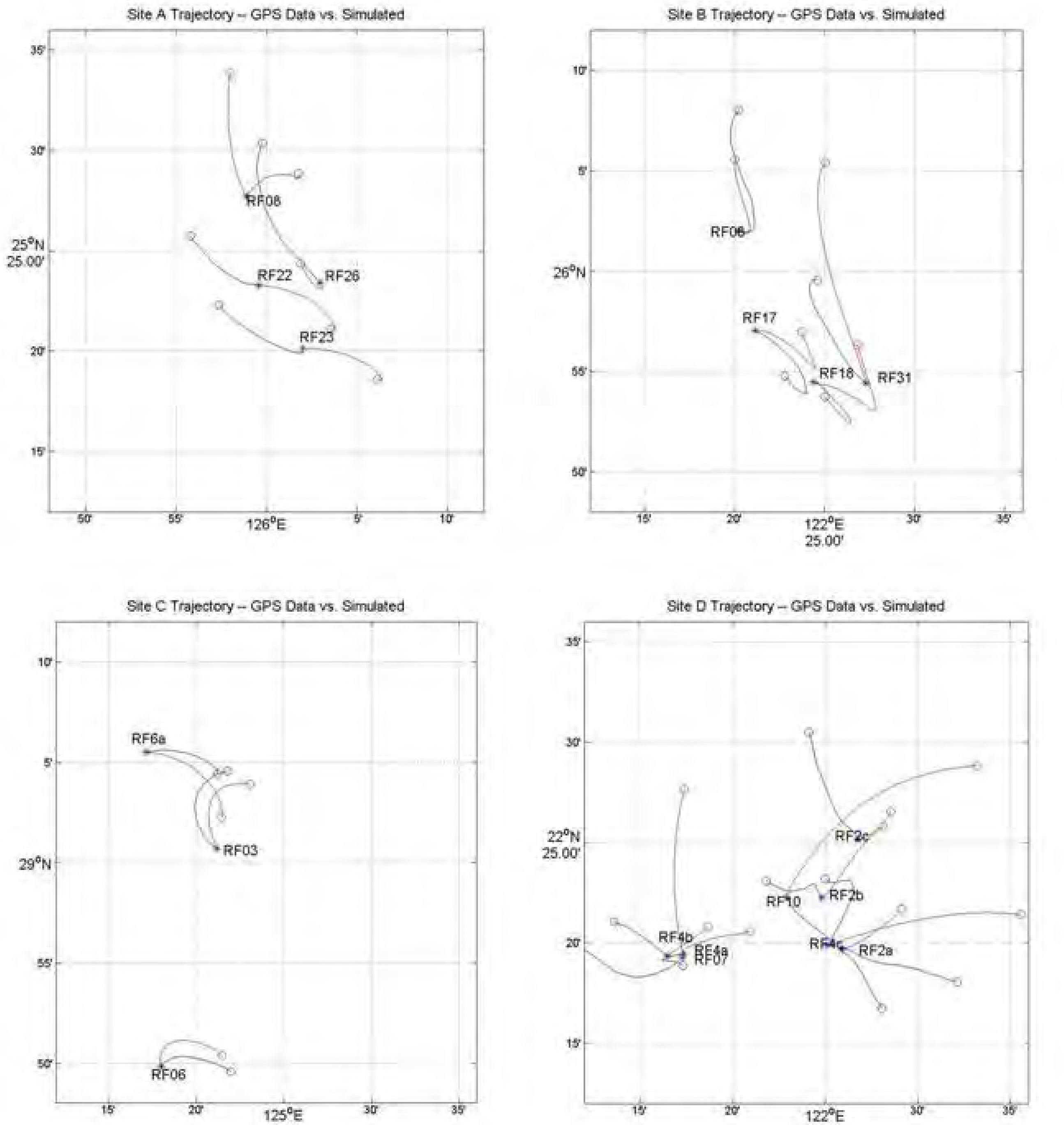

Figure 1: SFDM simulation results (red) and sonobuoy GPS data (blue) for the LWAD 06-1 sites A-D.

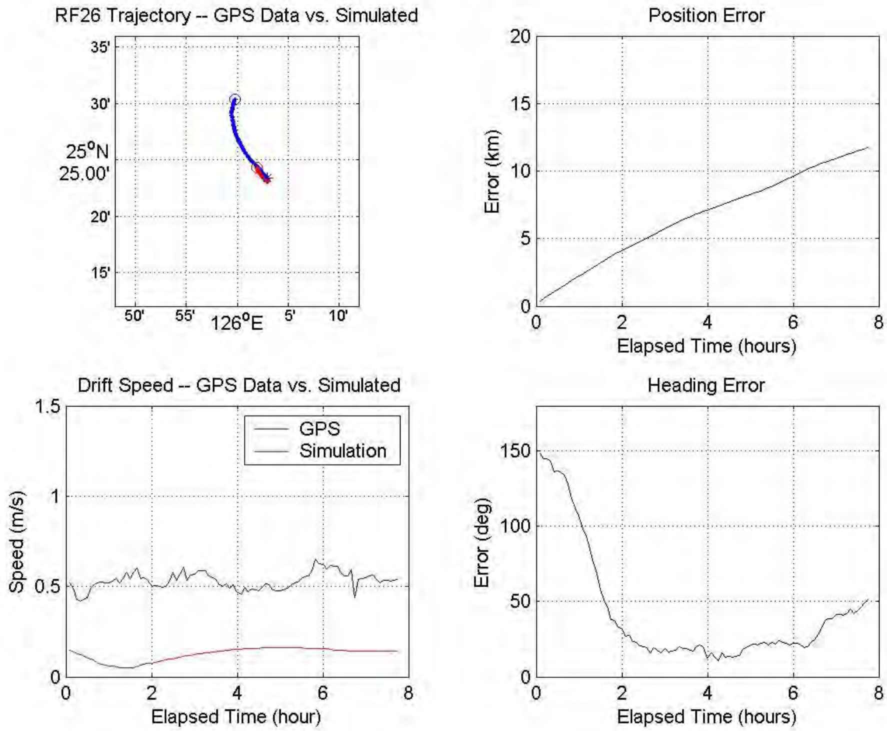

Figure 2: Site A Buoy RF 26 simulation results vs. GPS data summary.

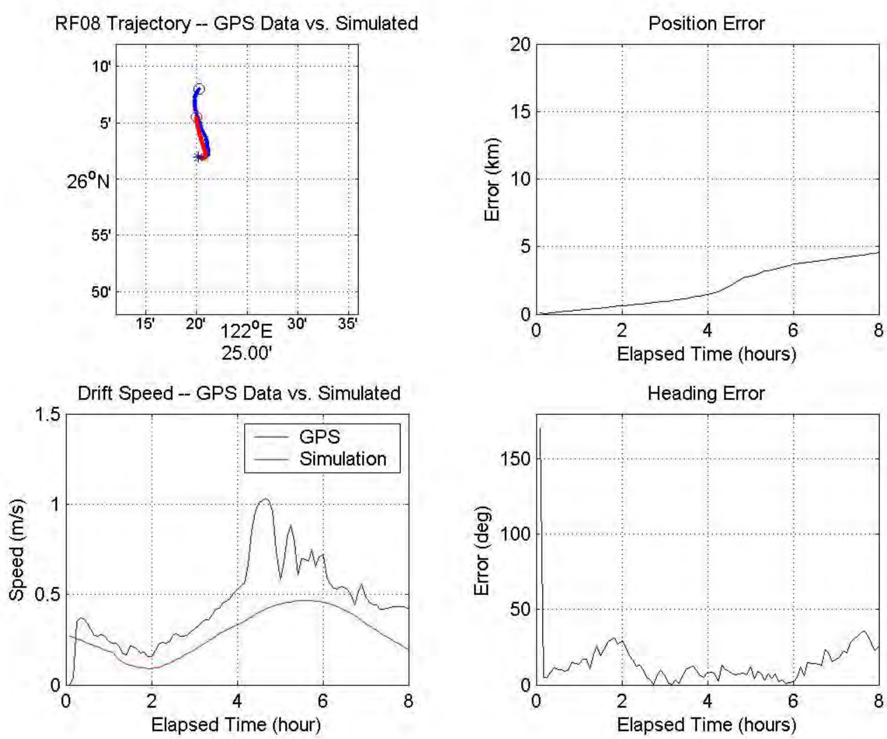

Figure 3: Site B RF08 simulation results vs. GPS data summary.

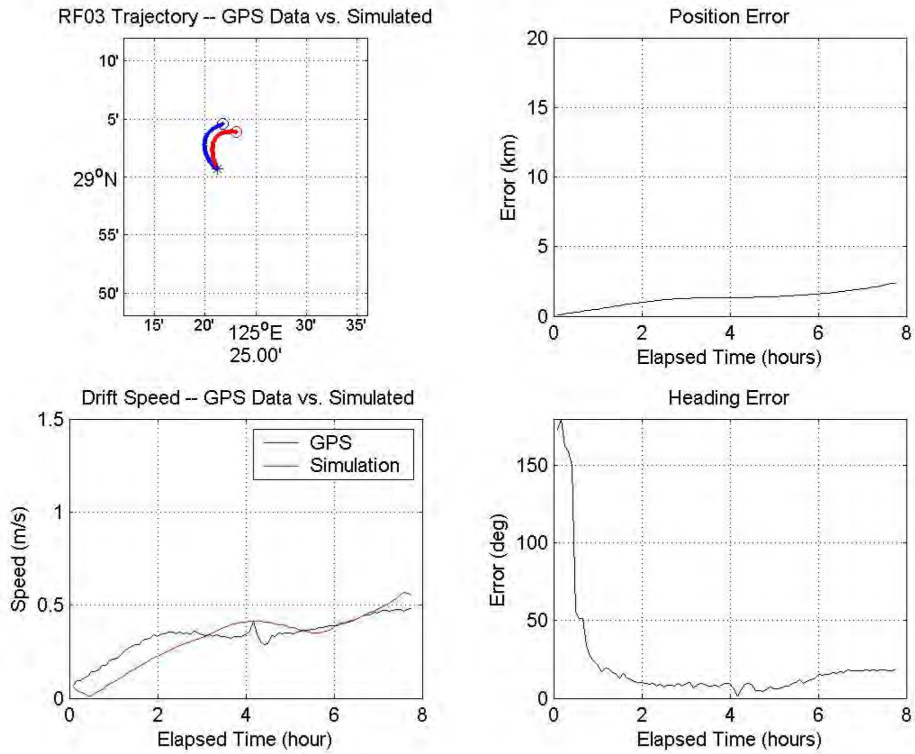

Figure 4: Site C RF03 simulation results vs. GPS data summary.

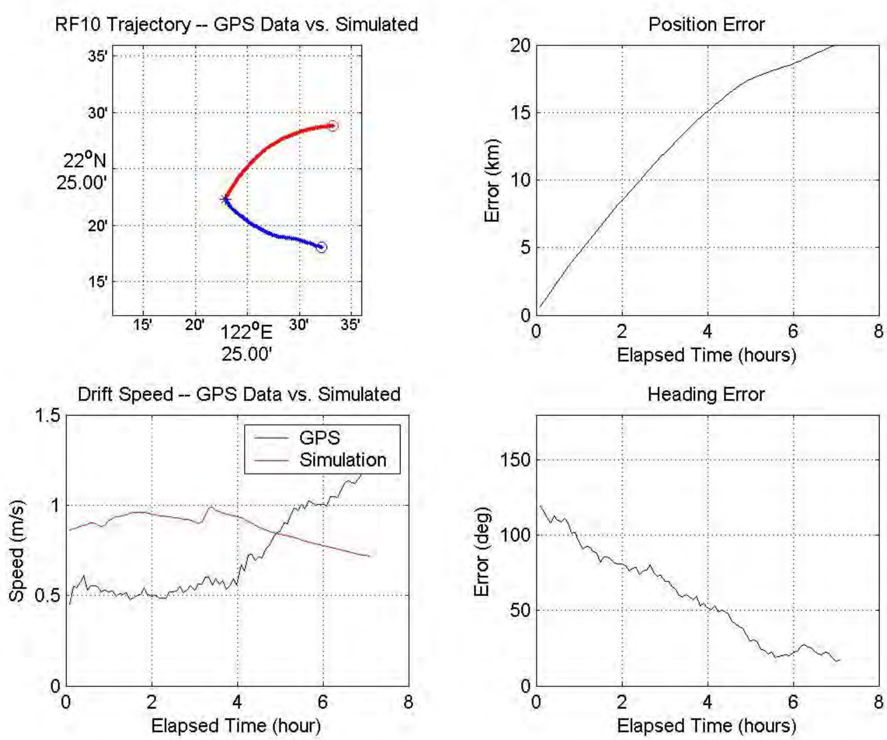

Figure 5: Site D RF10 simulation results vs. GPS data summary.

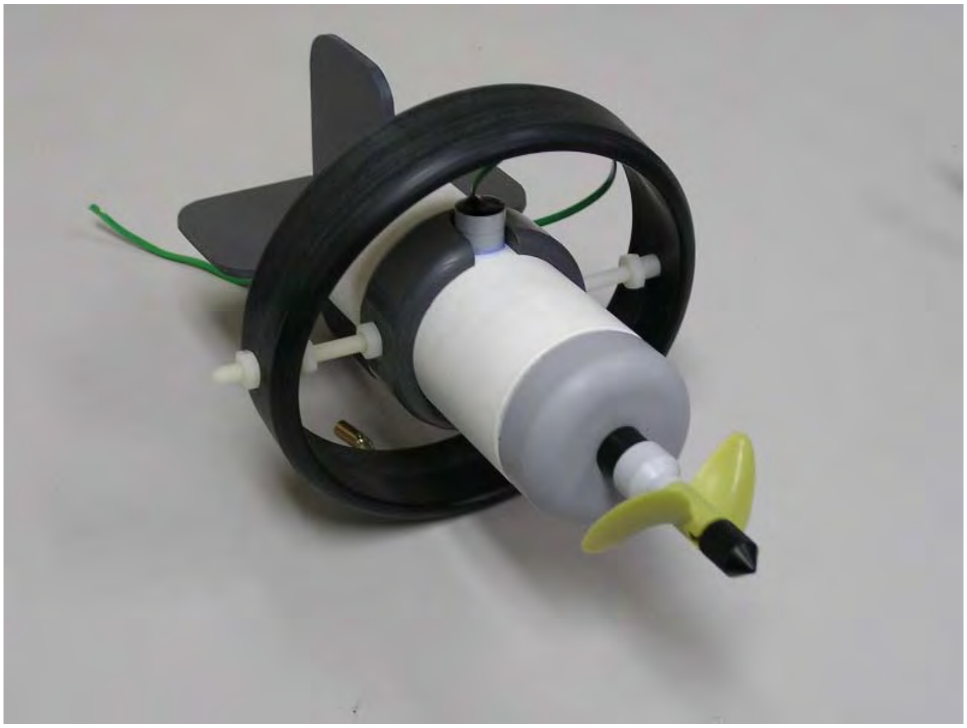

Figure 6: Impeller type relative flow sensor prototype.

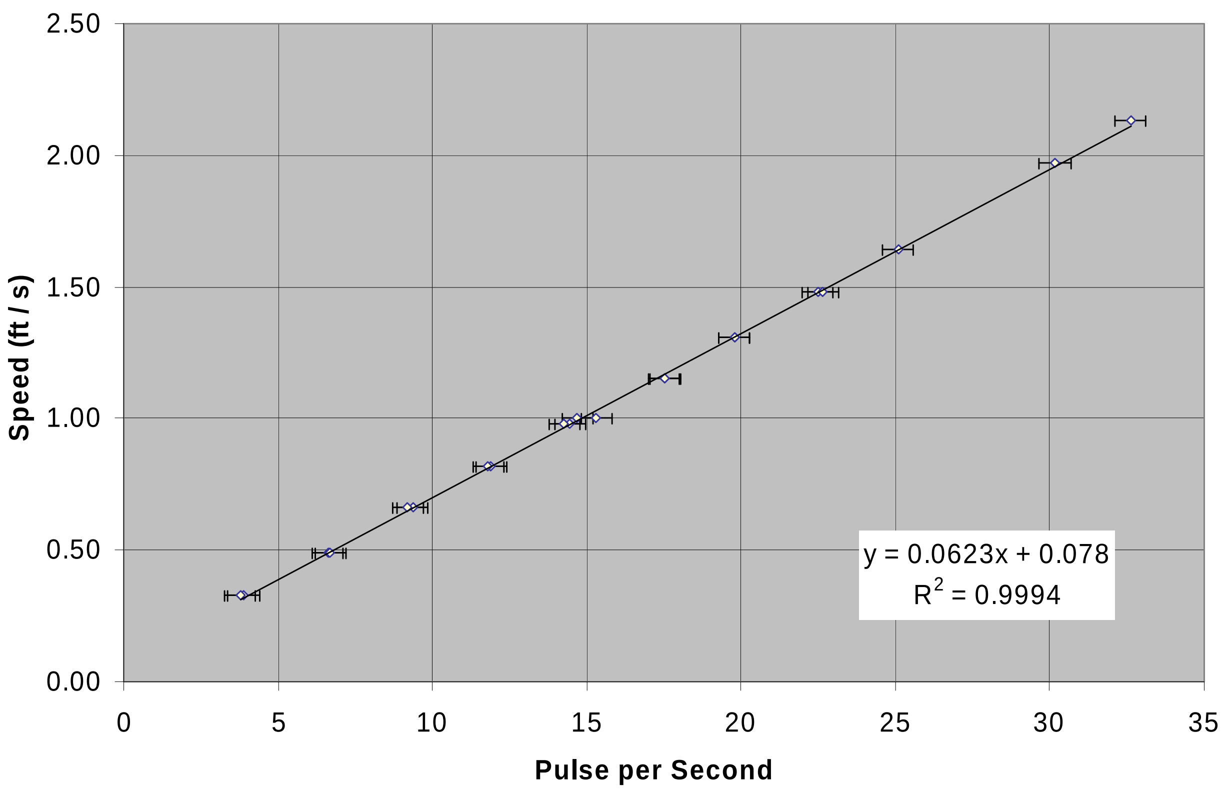

Figure 7: Tow data from the impeller design prototype relative flow sensor.

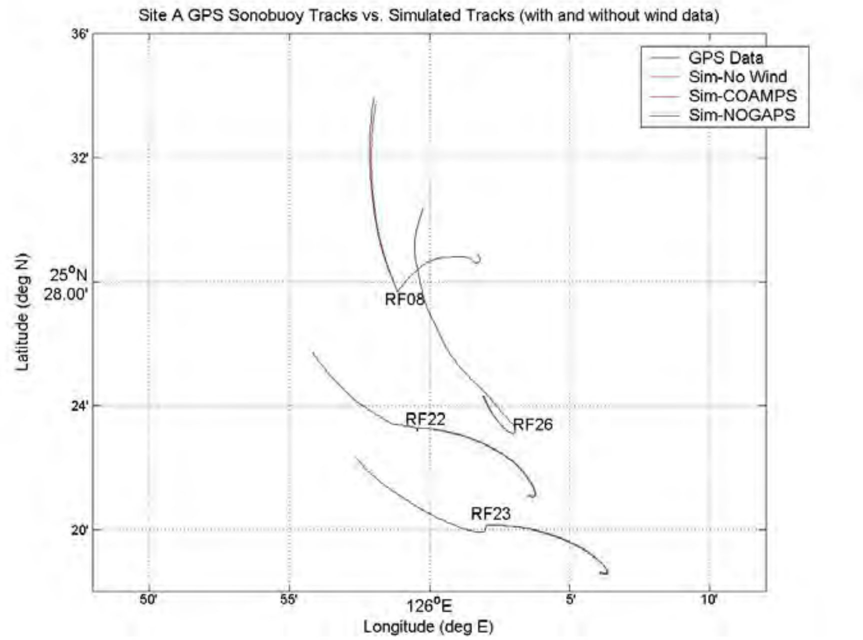

Figure 8: SFDM simulations results comparing no wind, with COAMP wind data and with NOGAPS wind data to the GPS data from sonobuoys at LWAD site A.

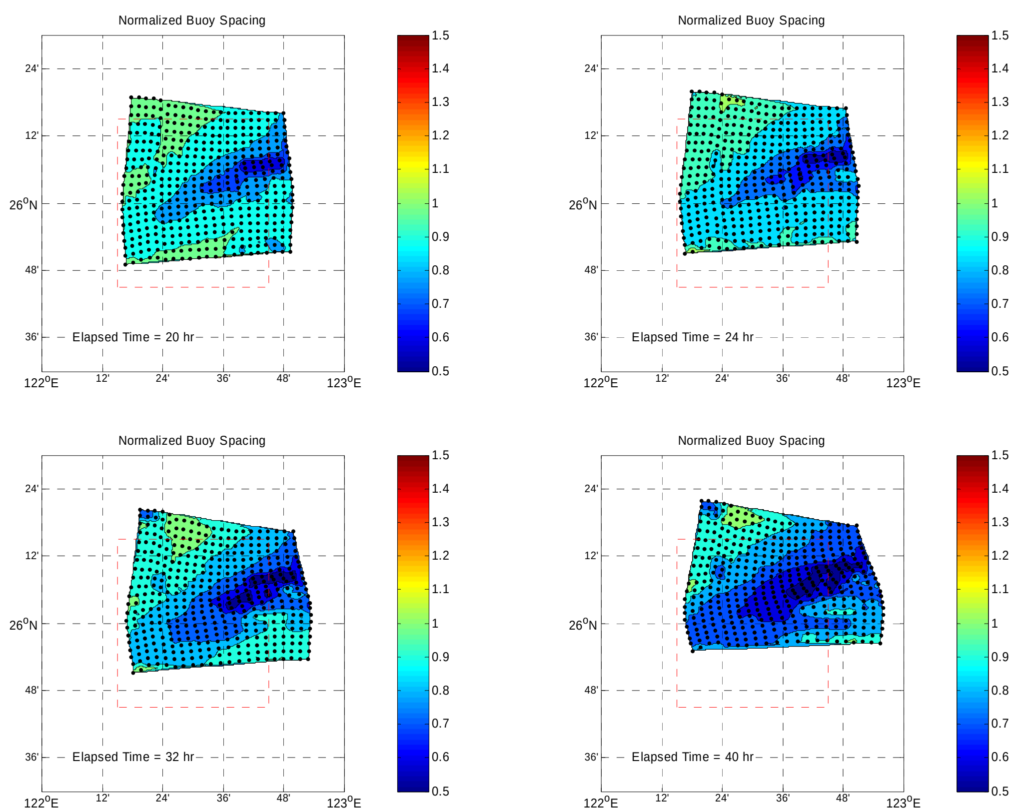

Figure 9: Normalized buoy spacing at LWAD 06-1 site B at hour 20, 24, 32 and 40 (initial deployment box indicated by red dashed line).

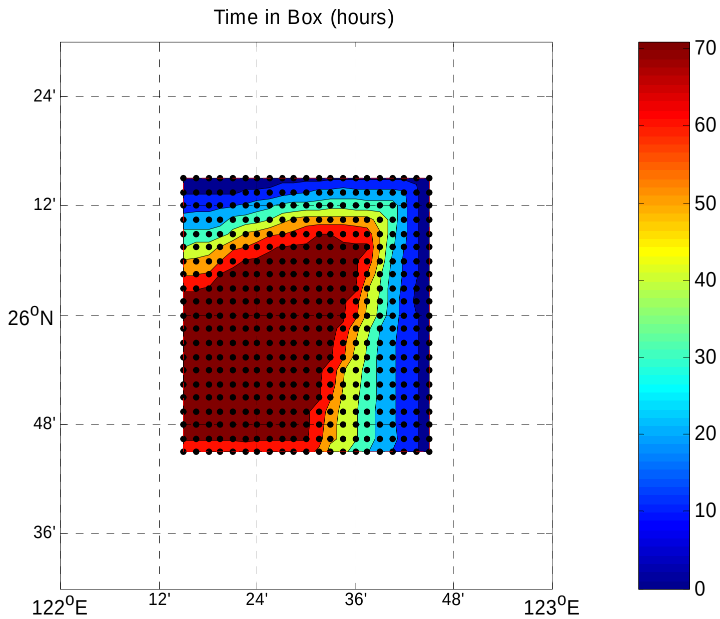

Figure 10: Sonobuoy residence time in a 1/2 deg x 1/2 deg box.